Appendix A

This appendix documents the Gunnison Basin Models and the changes that were made in support of the Upper Gunnison WMP effort. The original model documentation is not repeated here, but is referenced frequently. The goal of the appendix is to allow the reader to understand how Wilson Water Group refined the model to meet the needs of the project.

For the complete CDSS Gunnison Basin Model documentation, refer to the *Gunnison Historic CU* (2016) and *Gunnison River Basin Water Resources Planning Model User's Manual* (2016), found at https://www.colorado.gov/pacific/cdss/modeling-dataset-documentation.

This appendix also provides detailed information on the status of the existing data, the review process implemented by Wilson Water Group (WWG), how WWG refined the data, how the models were updated to include the refined data, and the appropriate application of the models.

Gunnison Basin Model Overview

The State of Colorado, through the Colorado Water Conservation Board (CWCB) and the Colorado Division of Water Resources, has developed and updated the Colorado Decision Support System (CDSS) to aid in water resources planning. The Decision Support System consists of a database of hydrologic and administrative information (HydroBase) related to water use in Colorado, and a variety of tools and models for reviewing, reporting, and analyzing the data. CDSS uses two primary models: consumptive use model platform (StateCU) and water right allocation model platform (StateMod).

HydroBase, StateCU, and StateMod were utilized for the Upper Gunnison WMP. The input data for the models was primarily derived from HydroBase. StateCU estimates the amount of water required by the crops or the irrigation water requirement (IWR), given the irrigated acreage, crop type, irrigation practices and efficiencies, and monthly time series of temperature and precipitation. This results in a good understanding of the existing crop demand. StateCU is used in the Gunnison WMP to estimate the amount of water delivered to the crops, based on historical diversion records, return flows from up-gradient ditches, irrigation practices and efficiencies. This results in a good understanding of current consumptive use. The difference between the IWR and the current consumptive use is the crop consumptive use shortage. Consumptive use shortage impacts crop yields and the economic viability of agriculture.

The existing crop demand, consumptive use, and shortage results from StateCU are reported in Section 3. Additionally, crop demand from StateCU is provided as input to the Gunnison Basin StateMod Model. StateMod is the best available tool for estimating the change in water available for beneficial use, both consumptive and non-consumptive, under varying hydrologic conditions. StateMod is a general water rights allocation model which determines availability of water to individual users and projects based on hydrology, water rights, delivery capacity, and demand.

The Gunnison Basin StateMod Model (Gunnison Basin Model) represents the full extent of the watersheds within the Upper Gunnison River Water Conservancy District – as well as all other watersheds in the Gunnison River basin, including complex operations associated with the Aspinall Unit reservoirs and the lower Gunnison River basin. The Gunnison Basin Model user documentation is available on the CDSS website and provides detailed information on model development, calibration, and operations.

The Gunnison Basin Model was first developed in 1994. The model was updated in the late 1990s and most recently in 2015. The model has a monthly Historical Calibration scenario and a Baseline scenario. The Historical Calibration scenario represents changing conditions through time and throughout the basin as accurately as possible. This historical representation was used to calibrate the model, with an emphasis on matching simulated and observed streamflow, diversions, and reservoir storage. As part of the Upper Gunnison WMP effort, the Gunnison Basin Model calibration was updated, as discussed in detail below.

The CDSS Baseline Scenario builds off the Historical Calibration scenario but applies only current demands and assumes all existing water resources systems were on-line and operational throughout the hydrologic model simulation period. Although historical diversions may have been limited by physical supplies (hydrology), legal (water rights) availability, or irrigation practices (such as user-decisions not to irrigate after haying); baseline agricultural demands represent full crop irrigation use. This allows the model to determine if historical shortages were due to physical or legal water limitations, providing an understanding of why there were agricultural shortages. This Baseline Scenario is an appropriate starting point for evaluating various “what if” scenarios over a long hydrologic time period containing dry, average, and wet hydrologic cycles

As indicated in the Gunnison Basin Model user documentation, the key results of the most recent major update (2015) to the Gunnison Basin Model prior to the UG WMP effort are as follows:

- A water resources planning model has been developed that can make comparative analyses of historical, current, and future water management policies in the Gunnison River basin. The model includes 100 percent of the basin's surface water use.
- The model has been calibrated for a study period extending from calendar years 1975 to 2013.
- The calibration in the Historical scenario is considered very good, based on a comparison of historical to simulated streamflow, reservoir contents, and diversions.
- A Baseline data set has been prepared which, unlike the Historical data set, assumes all existing water resources systems were on-line and operational for calendar years 1909 to 2013.

Upper Gunnison WMP Modeling Approach

The approach for the Gunnison WMP modeling was to start with the existing CDSS models and refine them to meet the needs of the project. In order to refine the models, the input data to the models needed to be evaluated and updated, if possible. WWG developed a review process and this appendix documents how the data was refined, how the models were updated to include the refined data and the appropriate application of the models. As part of the Gunnison WMP, the following information required for the Gunnison StateCU and StateMod models was reviewed and refined:

1. Streamflow measurements
2. Climate data
3. Irrigated acreage
4. Water rights
5. Diversion records
6. Irrigation practices
7. Return flow parameters

Additional discussion on the data assessment is found in Section 2.

Data Assessment and Refinement

The quality of model results is limited by the quality of the input data; high quality information provided to the model allows the model to produce high quality results. In order to provide the most useful Gunnison models possible, WWG needed to review the information used to generate model inputs. The review process identified several areas that needed refinement in order to allow the models to produce results on a finer temporal and spatial scale than previously developed. This section discusses the data components that required refinement and the limitations of available information.

Streamflow Measurements

The streamgage records are recorded by USGS include estimates. According to the USGS, the streamflow measurements for the majority of the gages are "good except for estimated daily discharges, which are poor". A good rating indicates that "95% of the daily discharges are between 10 and 15% of true value." Estimated daily discharges are generally reported in the winter months and are likely poor due to icing issues.

Diversion Records

As discussed in Section 2, diversion records in the basin lack the temporal resolution necessary for a daily model. Ideally, a daily model would be provided with the average daily diversion at each diversion structure. However, there are no diversions with continuous records, so average daily diversion records are not available. Instead, diversion records are composed of “spot-diversions” that are reported on an irregular basis by the water commissioner. This information is more appropriate for a monthly time step model, depending on the frequency of the spot measurements relative to changes in the diversion amount. However, the monthly time step was not useful for the Gunnison WMP because the issues of concern occur on a daily or even hourly scale. The diversion record limitations impose limitations on the model quality.

Irrigated Acreage

It is essential to accurately represent the irrigated acreage and the associated irrigation demand because the majority of consumptive water use is for irrigation. As part of CDSS, CWCB has developed irrigated acreage snapshots through time. As part of the WMP, the more recent CDSS 2015 irrigated acreage coverage was significantly enhanced specifically to better represent irrigation use. The primary enhancements relate to parcel size and water supply (ditch) assignment more than a bulk change in the overall acreage. The irrigated acreage assessment is outlined in more detail in Section 2. These changes were critical to allow the model to more accurately determine physical and legal availability of water and any associated shortages, a critical component of the WMP needs assessment. In addition, streamflow estimates between structures also improved due to the more accurate representation of irrigation demands.

Return Flow Parameters

Representing return flow quantities, locations, and timing are critical for understanding current conditions in the basin and for investigating how changes to current irrigation practices impact downstream flows. Many of the opportunities to improve watershed health include changes in irrigation use, including efficiency improvements.

Existing return flow parameters were developed on a courser scale than was needed for the Gunnison WMP. The return flow parameters were reviewed and refined by WWG to account for the finer scale required.

Return Flow Quantities

Return flows are generally considered in two components; return flows from ditch seepage and return flows from field irrigation application. In previous CDSS efforts, lack of information necessitated that these two return flow components be combined. For the StateMod model to be useful in predicting changes to return flows and associated water available for downstream water rights, and changes to streamflows for specific demonstration projects and future identified options, it was critical that the two components of return flows be disaggregated and refined.

The first component of return flows is from ditch seepage as water is conveyed to the irrigated acreage, represented in the models as conveyance efficiency. Understanding conveyance efficiencies allows a better estimate of diverted water that makes it to the farm for irrigation use. Prior to the Stream Management Planning process, ditch alignments had not been mapped for the majority of ditches in the Upper Gunnison Basin – either digitally in GIS or on paper maps. As part of matching funding for the project, DWR provided funding for WWG to develop ditch alignment GIS coverage for the entire Upper Gunnison Basin. Previously, DWR used GPS to site river headgate locations. The headgate information, along with the updated irrigated acreage assessment, was used to create the initial ditch line-work. WWG relied on the local water commissioners for review and approval of the effort. Each ditch alignment was assigned to the water district identifier in the GIS attribute table; allowing a link between the headgate GIS coverage and the irrigated acreage GIS coverage. WWG worked with CWCB to assure the process and review were documented in the GIS metadata and the coverage made available on the CDSS website. The resulting ditch lengths, along with statewide soil parameter coverages were used to better understand and quantify conveyance efficiencies. The NRCS has developed relationships between ditch length and soil types. These relationships are found in the *Farm irrigation Rating Index (FIRI) - A method for planning, evaluating, and improving irrigation management* (June 1991) and are used for this project. The ditch conveyance efficiencies, coupled with estimated or reported diversions, are used to quantify ditch seepage. During WWG interviews with water users in the basin, WWG confirmed that the estimates of ditch seepage were reasonable. Water users agreed with our average values, with the caveat that ditch seepage can be significantly higher than the average values at the beginning of the season.

The second component of return flows is generated from on-field irrigation application. Information from decrees, soil parameter coverages, and UGRWCD staff indicate that the local gravelly soils, coupled with flood irrigation, allow a maximum application efficiency of 45 percent. Unlike ditch conveyance efficiency, application efficiency varies significantly with water supply, as it takes much more effort to be efficient. In general, application efficiencies are lower during the higher runoff period and in wet summers. Application efficiencies approach 45 percent in the later irrigation season in normal years and throughout the season in dry years. The maximum application efficiency is a function of both crop irrigation requirements and estimated or reported diversions and is calculated by both CDSS models.

Return Flow Locations

The CDSS modeling effort generally estimated that return flows accrued to the river above the next downstream ditch. As discussed above, significant effort was made to refine StateMod return flow locations for both ditch seepage and application losses, which is critical for understanding how changes would impact water users and streamflow. The primary information source was GIS mapping, including the ditch alignment coverage, irrigated acreage coverage, topographic coverages, and coverages showing local drainages and tributaries. Information from interviews with water users and the water commissioner was used to supplement and enhance return flow locations for the larger ditches. As discussed in Section 2, information from the interviews was used to understand and represent irrigation surface return flows that accrue directly to down-gradient ditches.

In many parts of the Upper Gunnison Basin, return flows do not simply re-enter the stream. This is a relatively unique set-up and is not common in other parts of Colorado. In these cases, return flow moves across the surface of fields and through the sub-surface groundwater system, and directly enter the next down-gradient ditch. Therefore, these return flows serve as a supply to a down-gradient ditch or irrigated parcel without being measured at the down-gradient ditch headgate. The ramifications of this are significant. In areas with high concentrations of irrigated parcels (i.e. the lower East River and Ohio Creek), water is diverted and measured at up-gradient headgates, some of which is immediately consumed by the hay crop. Surface return flows often are capture and reused by down-gradient ditches without re-entering the river. This unmeasured supply can be significant for the down-gradient ditch and help eliminate consumptive use shortages. It also means that the StateMod model needs to have the correct return flow locations, or the model will simulate incorrect amounts of streamflow between diversion headgates.

Return Flow Timing

A portion of return flows from irrigation application "runoff" directly to drainages, tributaries, or down-gradient ditches within a few days of irrigation application, while a portion of return flows percolate through the ground water alluvium and lags back to the river over several days or months. Based on information from water users and decrees, and CDSS investigations, it was estimated that the portion of return flows from diversion and subsequent flood irrigation that return quickly as surface runoff is as high as 50 percent.

A common method for estimating return flows that lag through the ground water system is the Glover analytical solution. The method requires estimates of alluvial aquifer properties, generally obtained from pump tests performed on existing high-capacity wells. Review of available information did not yield additional ground water property information beyond what was used in CDSS to estimate return flow lagging patterns in the upper Gunnison River basin. The existing CDSS patterns were discussed with water users and the water commissioner and determined to be appropriate for continued use.

The existing CDSS patterns were used in the Gunnison Model and are described in the *Gunnison Model User's Manual* (2016) as:

- Instantaneous (within the same time step as the diversion) returns,
- Artificial snowmaking returns in the fourth month following the diversion,

- Irrigation return flow pattern, which represents both surface water and shallow groundwater returns

The existing irrigation return flow pattern assumes that a portion of return flows will occur as surface water returns, such as tailwater or flood irrigation application water that did not soak into the ground, and a portion will occur as shallow groundwater. Note that incidental losses in the Gunnison are estimated to be 3 percent of unused water. This accounts for water lost to the hydrologic system through non-crop consumptive use, deep groundwater storage, or evaporation. It is assumed the incidental losses occur in the same month as diversions.

In order to correctly represent the timing of return flows for the daily model, two new irrigation return flow pattern was developed: daily irrigation immediate return flows and daily lagged return flows. Discussions with water users suggested that irrigation immediate return flows appear the day after diversion and last for approximately three days. The daily lagged return flows represent irrigation water that has soaked into the ground and is slowly seeping into a stream or down-gradient ditch. The timing of the lagged return flows is shows in Figure 1.

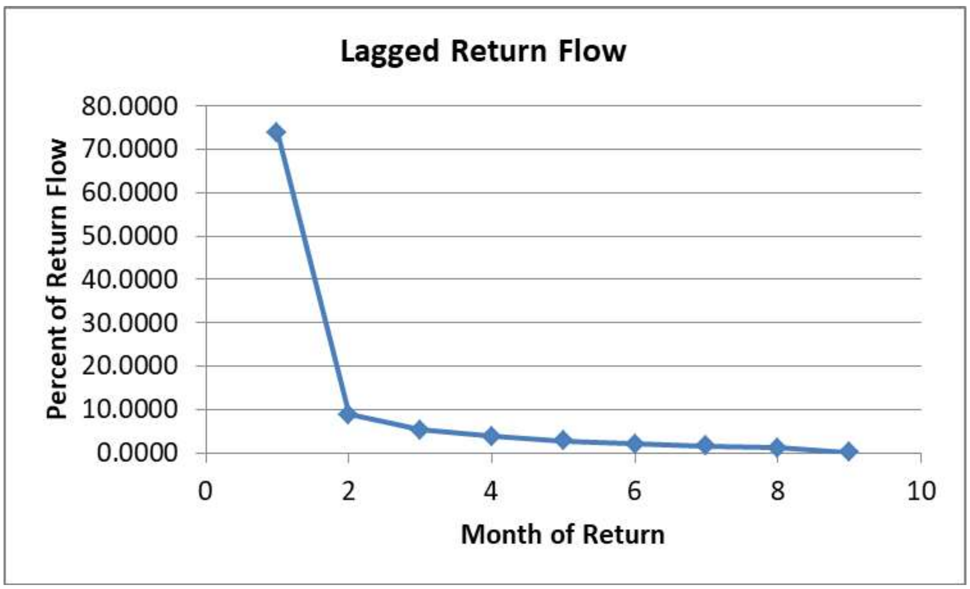

Figure 1: Monthly Lagged Return Flow Pattern developed for Upper Gunnison WMP

UG WMP Model Enhancements

The Gunnison Basin Model underwent significant updates as part of the WMP effort. These updates were based on data collection and user-interviews so that individual reaches could be better represented and evaluated for impacts to existing consumptive and non-consumptive uses. As discussed in Section 2, the data collection and user-interview process also highlighted uncertainties in data that is available for model development. Based on the data collection efforts, it is important to stress that the model should not be relied upon to provide absolute information, including predicted reach streamflows. Instead, the model should be used to compare “what if” scenarios. For example, the model can examine how water availability changes with new demands or operations. Note that this is how the StateMod platform has been used in the past for state-wide water planning efforts, such as the Colorado Water Plan.

For the Gunnison WMP effort, the modeling team focused on refining the Historical Scenario. The updates to the Gunnison Model included incorporating the reviewed and refined data discussed above. Specific enhancements are:

- Incorporating the updated irrigation assessment developed for the UG WMP.
- Disaggregating irrigation diversions so that each headgate is represented as a single structure.
- Updating return flow locations to represent the disaggregated diversions and to capture return flows that move directly into down-gradient ditches, without returning to the stream.
- Representing both conveyance efficiency and irrigation application efficiency, instead of the previous model representation of overall system efficiency.
- Increasing explicit representations of tributaries (added Perry Creek, Coal Creek, Washington Gulch, Pass Creek, Middle Creek, Willow Creek, Henson Creek, and Elk Creek to model).
- Including explicit representation of municipal/industrial water users (Town of Crested Butte, Mount Crested Butte Water and Sanitation District, Mount Crested Butte snowmaking, and Lake Fork City).
- Adding representation of Lake San Cristobal.
- Adding the transbasin import from Lake Irwin to Coal Creek.
- Increasing the number of instream flow reaches explicitly represented.
- Extended the model period from 2013 through 2017.
- Updated the natural flow distribution to ungaged locations.
- Converting the model from a monthly to a daily timestep (discussed in more detail below).
- Re-calibrating the monthly and daily model.

Structure Disaggregation

An important enhancement to the Gunnison Basin Model that directly supports the UG WMP effort involved disaggregating structures within the model and refining return flow location assumptions. The 2015 version of the model was developed with the main purposes of performing basin-wide, comparative analysis such as shortages or impacts of reservoir operations. For this purpose, representing smaller ditches as a single “aggregated” structure was appropriate. However, the UG WMP goals require streamflow to be evaluated at a higher resolution, reach by reach, and thus each ditch in aggregated model structures is now represented individually at the location of diversion.

Once the diversions were more discreetly represented, another important step included improving return flow location assignments. As noted above, previous versions of the model were intended for more course comparative analysis at a monthly timestep. The UG WMP's disaggregation enabled the model to more precisely identify where return flows, mainly from flood irrigation, re-entered the stream. Information gained from meetings with the Water Commissioner and irrigators helped inform these updated return flow location assignments.

Daily Timestep

One of the most significant changes to the Gunnison Basin Model was the conversion from a monthly timestep to a daily timestep. From a project evaluation and water resources planning standpoint, a monthly timestep is typically appropriate; therefore, the CDSS modeling focuses on development and updates to monthly models. For the UG WMP effort, daily information was needed to assess impacts on non-consumptive needs. Note that the daily model routine in StateMod does not include streamflow routing. While this is not appropriate for an operational model, it is appropriate for a planning model and for use in comparative modeling.

To convert from a monthly timestep to a daily timestep, the monthly naturalized streamflow is distributed to daily timestep based on pattern gages. This preserves the volume of the monthly naturalized streamflow. The daily pattern gages are selected by location to best represent natural conditions. Care was taken to find suitable pattern gages that resulted in good calibration and captured the timing of snowmelt. The daily pattern gage approach requires a complete daily gage record; therefore, due to data availability limitations, the daily model simulation period represents the more recent hydrologic time period of 1998 through 2017. The period from 1998 through 2013 includes dry, wet, and average runoff cycles; plus represents current basin operations and administration.

To convert the monthly diversion demands to daily, the monthly diversion demands were distributed based on a linear interpolation between the monthly mid-points. This option also allows the continued use of monthly irrigation water requirements from the StateCU model. The drawback to this approach is that irrigation practices, such as turning off diversions to dry the field before cutting hay, or gentleman's agreements to rotate diversions between ditches to share the limited supply, are not represented in the daily model. However, the lack of daily diversion records seriously limits the available options for a daily model.

Daily instream flow demands are represented based on their water rights.

Natural Flow Development

Natural flow development is a key step in building a StateMod model. This process is documented in the *Gunnison Basin Model User's Manual* and summarized below.

In order to simulate river basin operations, StateMod begins with an estimate of the amount of water that would have been in the stream without the impact of man. These "Natural Flows" allow any future water right or operating strategy to be imposed on a naturalized historical hydrologic sequence. StateMod estimates naturalized flows at streamgages based on gaged flow, historical diversions, reservoir operations, water use efficiency and return flows. This process is performed prior to a simulation so that the resulting naturalized flow file becomes part of the input data set for a subsequent simulation. Naturalized flow estimation requires a minimum of two steps: 1) adjust gaged flows using historical records; and 2) distribute gains above and between gages to user-specified, ungaged naturalized flow nodes.

Natural Flow Calculation at Gages

Natural flow at a site where historical gage data is available is computed by adding historical values of all upstream depletive effects to the gaged value, and subtracting historical values of all upstream augmenting effects from the gaged value:

$$Q_{Natural} = Q_{Gage} + Diversions - Returns - Imports +/- \Delta Storage + Evap$$

Historical diversions, imports, and reservoir contents are provided directly to StateMod to make this computation. Evaporation is computed by StateMod based on historical evaporation rates and reservoir contents. Return flows are similarly computed based on diversions, crop water requirements, conveyance and application efficiencies, and return flow parameters.

Natural Flow Distributed to Ungaged Points

In order for StateMod to have flow on tributary headwaters, natural flow must be estimated at all ungaged headwater nodes. In addition, gains between gages are modeled as entering the system to reflect increased flow due to unmodeled tributaries.

StateMod has an operating mode that distributes a portion of natural flow at gaged locations to ungaged locations based on drainage area and average annual precipitation. The default method is the "gain approach". In this approach, StateMod pro-rates natural flow gain above or between gages to ungaged locations using the product of drainage area and average annual precipitation. A second option for estimating headwater natural flows can be used if the default "gain approach" method created results that do not seem credible. This method, referred to as the "neighboring gage approach", creates a natural flow time series by scaling the natural flows at a specified gage. This approach is effective when the runoff at an ungaged location does not follow the same pattern as the gains along the main stem. For example, a small ungaged tributary that peaks much earlier or later than the main stem should use the neighboring gage approach with a streamgage in a similar watershed.

Natural Flow Refinement

For the Upper Gunnison WMP model, the natural flow estimates at ungaged locations were refined based on the addition of new tributaries and information provided by the water commissioner and water users.

Figures 2 through 8 show the average monthly natural flow and the observed streamflow at USGS gages throughout the basin from 1998 through 2017, or the period of record for the gage. The difference between the natural flow and the observed streamflow are depletions from consumptive use and retiming of water due to lagging of return flows.

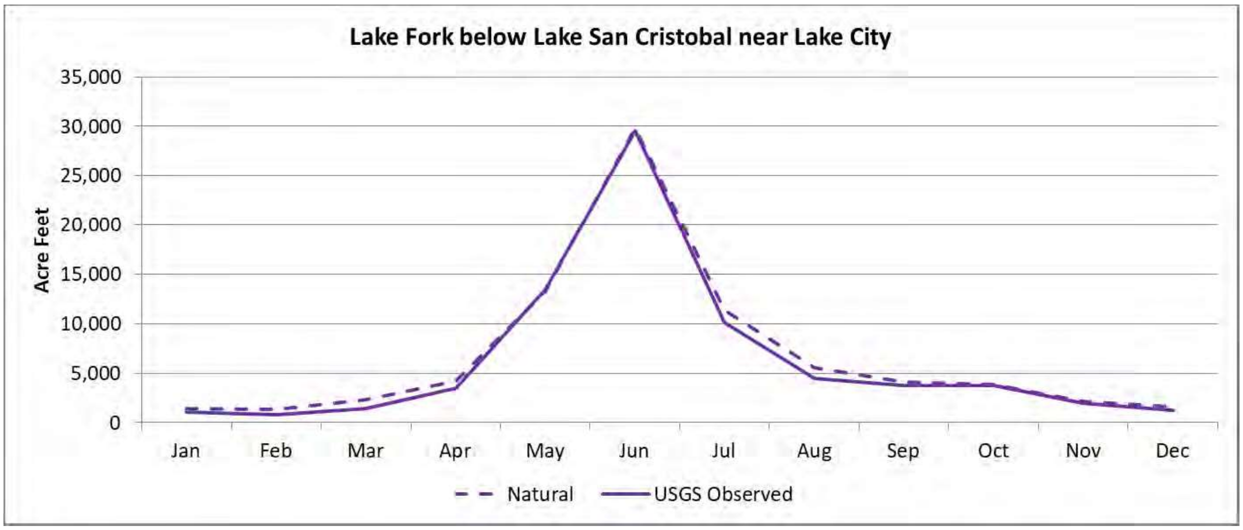

Figure 2: Monthly Average Natural Flow and USGS Gage Flow - Lake Fork below Lake San Cristobal near Lake City, 2012-2017

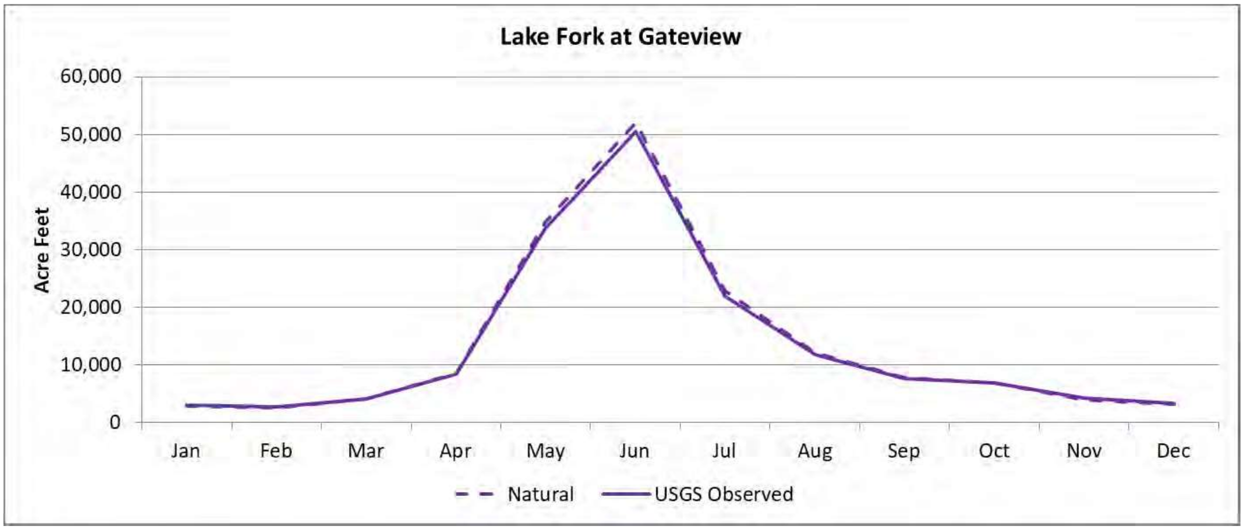

Figure 3: Monthly Average Natural Flow and USGS Gage Flow - Lake Fork at Gateview, 1998-2017

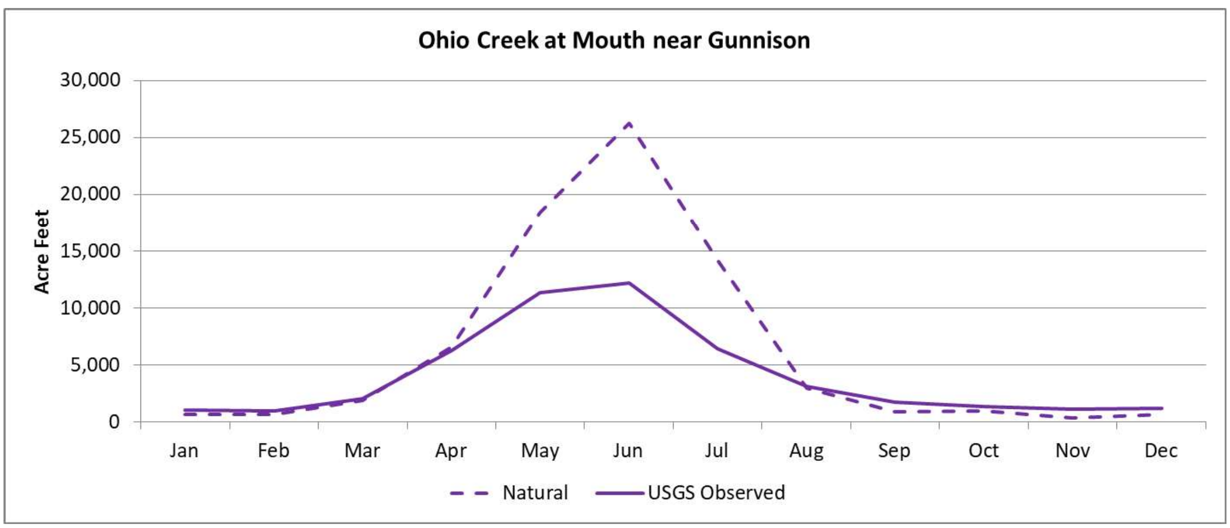

Figure 4: Monthly Average Natural Flow and USGS Gage Flow - Ohio Creek at Mouth near Gunnison, 1999-2017

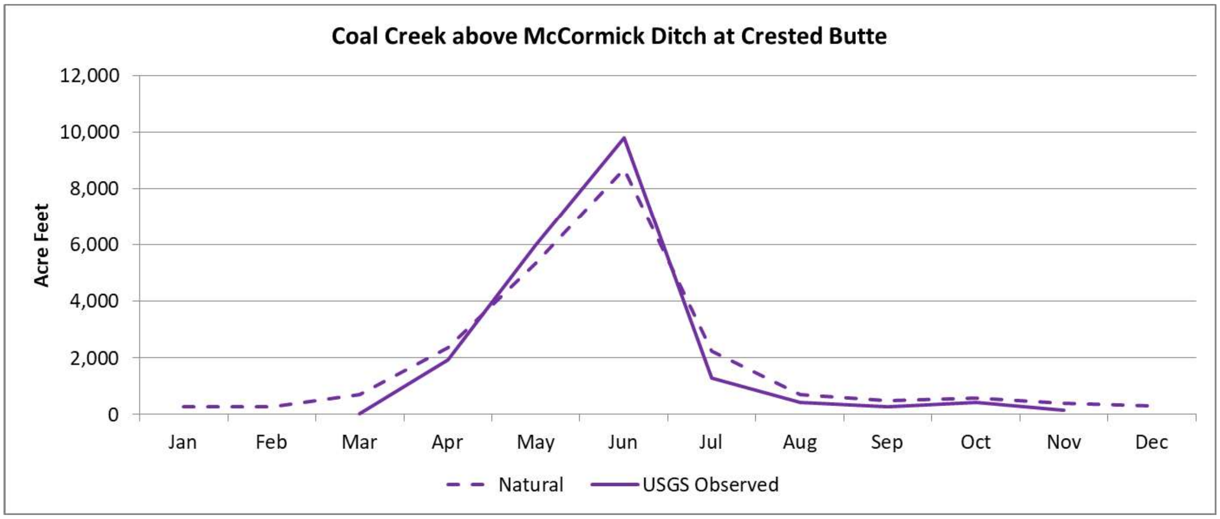

Figure 5: Monthly Average Natural Flow and USGS Gage Flow - Coal Creek above McCormick Ditch at Crested Butte, 2015-2017

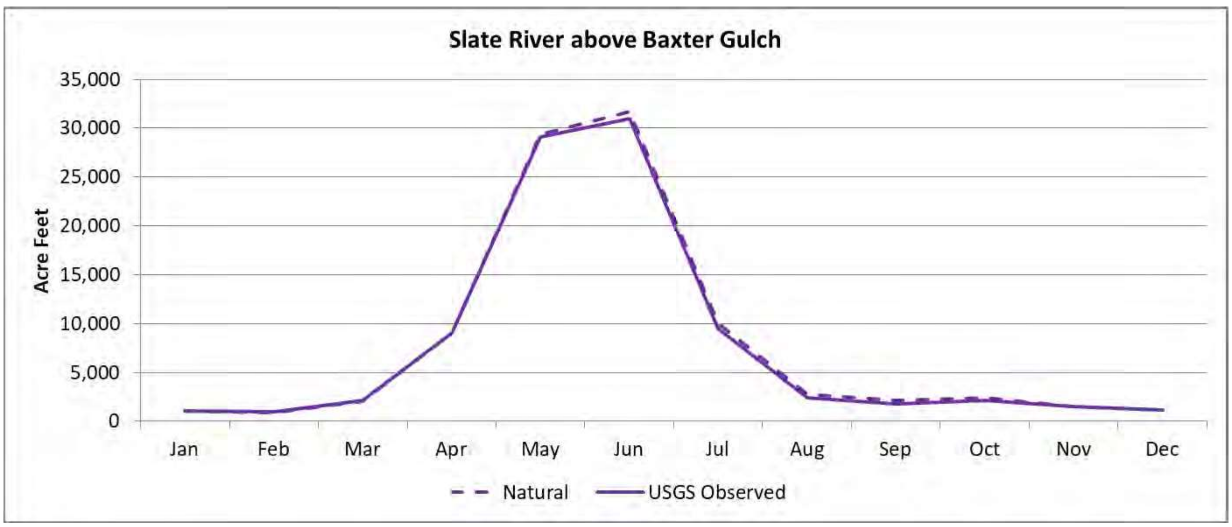

Figure 6: Monthly Average Natural Flow and USGS Gage Flow - Slate River above Baxter Gulch, 1998-2017

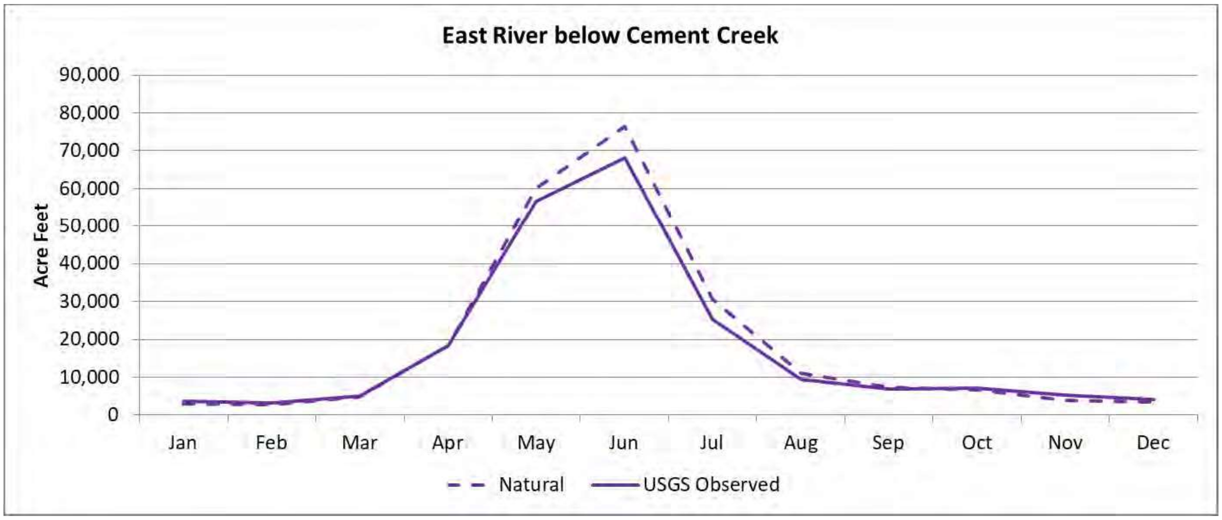

Figure 7: Monthly Average Natural Flow and USGS Gage Flow - East River below Cement Creek, 1998-2017

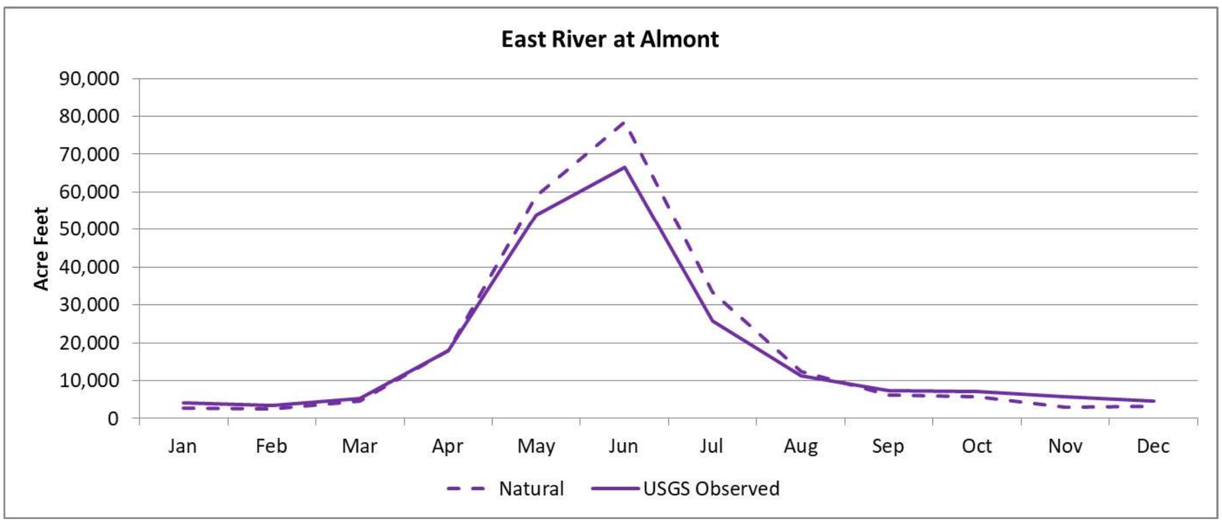

Figure 8: Monthly Average Natural Flow and USGS Gage Flow - East River at Almont, 1998-2017

Model Calibration

The original monthly calibration for the Gunnison Basin Model is considered very good and was improved with the updates made as part of the UG WMP effort, specifically updates to irrigated acreage and return flow locations (described above). The Gunnison Basin Model was re-calibrated at a monthly timestep before converting it to daily; then calibration was also confirmed on a daily basis. As discussed in Section 2, water-users and the water commissioner indicated that there has been cooperation among water users, both within the East River basin and downstream, to share limited supplies and purposefully not place a water rights call on the river. The decision was made to maintain historical water right priorities within the basin and allow representation of the legal priority system. This is consistent with the State of Colorado's approach to StateMod modeling and is a conservative assumption. Because in most years diversions are much less than observed streamflow, this representation results in good calibration.

Figures 9 through **23** show daily streamflow calibration results at three streamflow gage locations in the Upper Gunnison basin: Slate River above Baxter Gulch, East River below Cement Creek, East River at Almont, Ohio Creek above the Mouth near Gunnison, and Lake Fork at Gateway. Time series graphs are shown for both the full daily simulation periods (1998-2017) and for a shorter, more recent period (2010-2012). The period 2010 through 2012 was chosen to highlight because it includes a very wet year (2011), a very dry year (2012), and a relatively average year (2010). In dry years, the model is limiting diversion in order to satisfy senior users; therefore, the model shows more streamflow than was historically observed when senior users did not place a call. This is highlighted in **Figures 19** and **22** for the 2012 dry year.

In general, the model does an excellent job of replicating observed streamflow during both wet and dry year types. In addition, a scatter plot for the full daily simulation period is presented for each location, showing a high correlation between observed and modeled streamflow. The equation on each graph has the y-intercept set to zero and indicates that there is nearly a one to one relationship between observed data and model results. In addition, the correlation coefficient (R^2) is very close to 1.0 which means that there is high agreement between the observed and model results.

Figures 12 through **14** for Ohio Creek above the Mouth near Gunnison show the poorest calibration. This is due to the lack of a continuous daily gage record for the model period of record (1998 through 2017) in Ohio Creek. Therefore, the pattern gage selected to disaggregate the monthly natural flow to daily is the combined Slate River at Baxter Gulch and Slate River at Crested Butte gages. Although the watersheds are similar, they are not identical. The Slate River gages do not exactly capture the timing of runoff and late season draw down in the Ohio watershed.

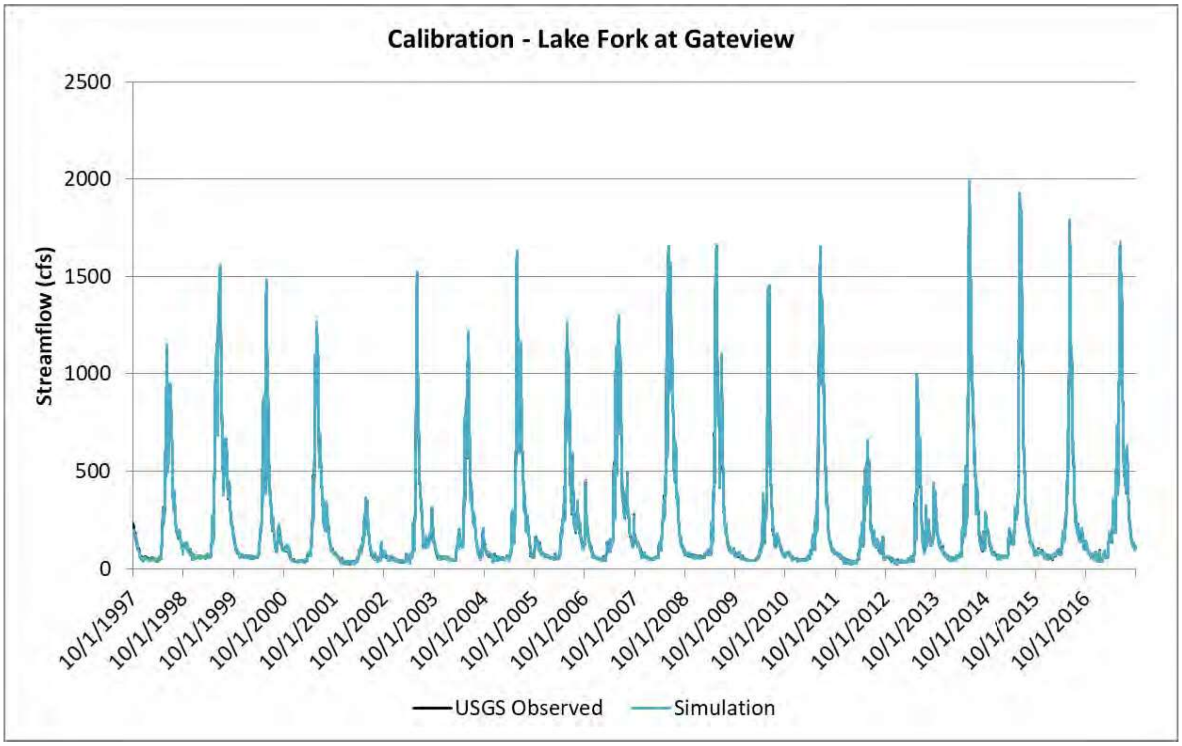

Figure 9: Daily Calibration Time Series - Lake Fork at Gateview, 1998-2017

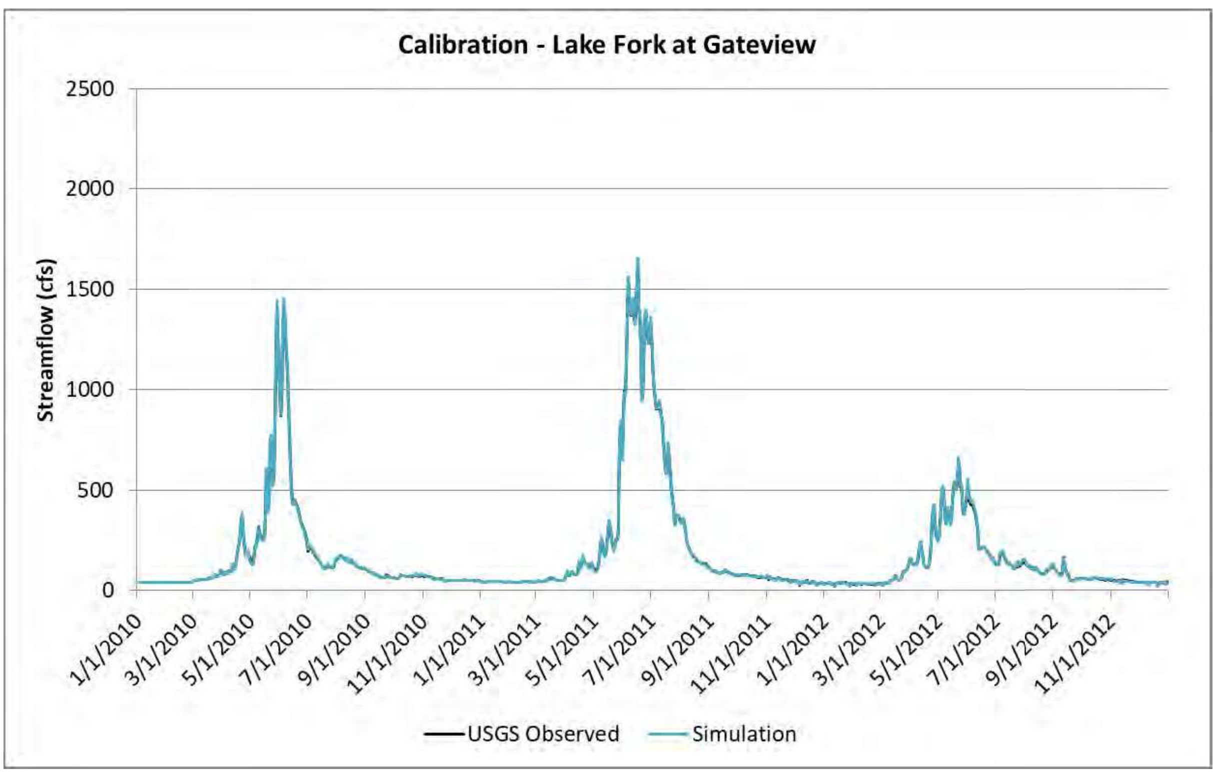

Figure 10: Daily Calibration Time Series - Lake Fork at Gateview, 2010-2012

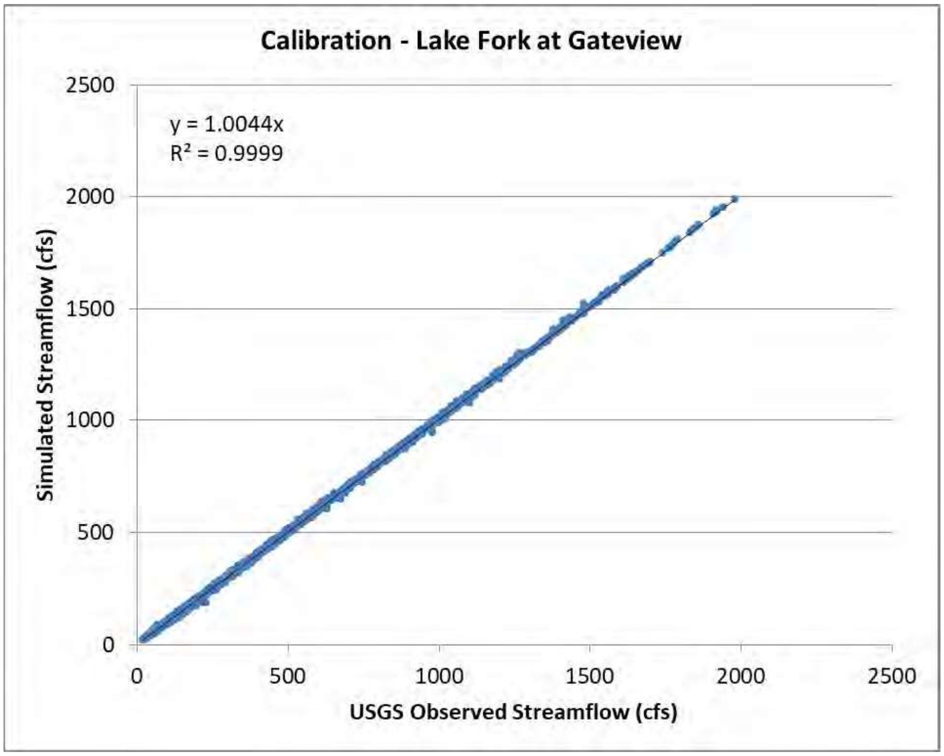

Figure 11: Daily Calibration Scatter Plot - Lake Fork at Gateview, 1998-2017

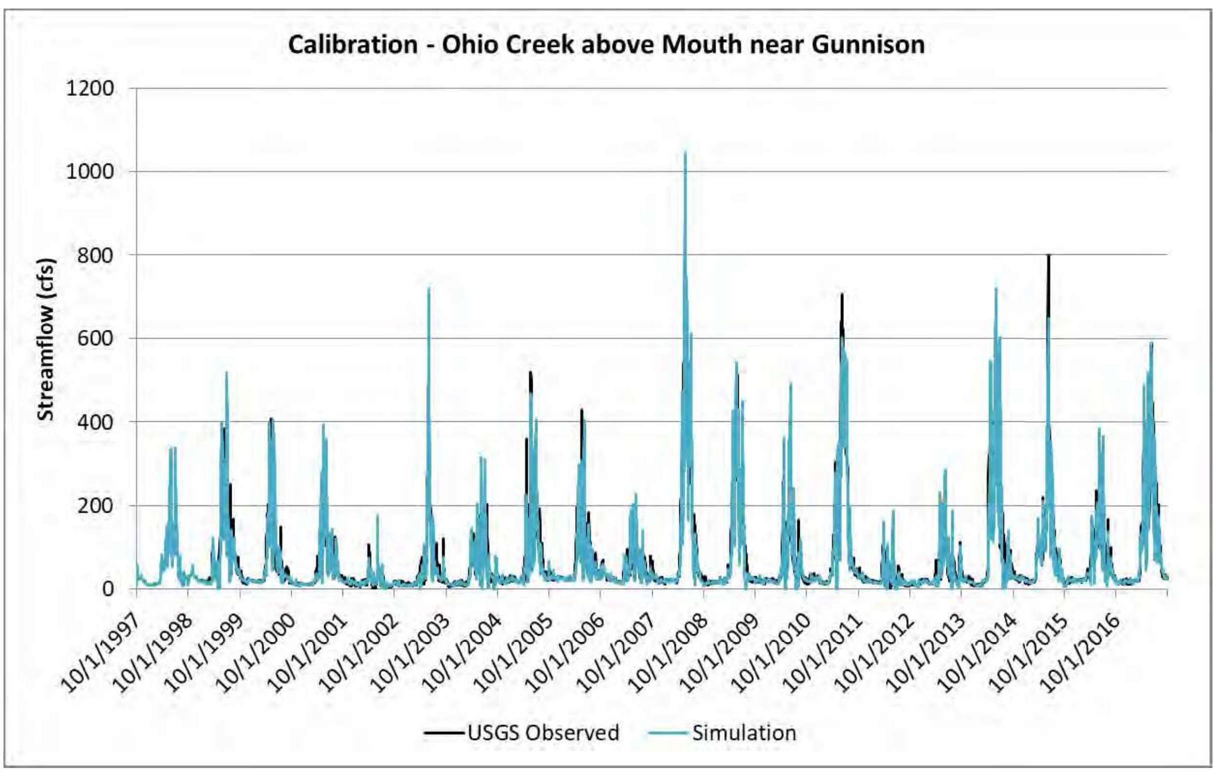

Figure 12: Daily Calibration Time Series - Ohio Creek above Mouth near Gunnison, 1998-2017

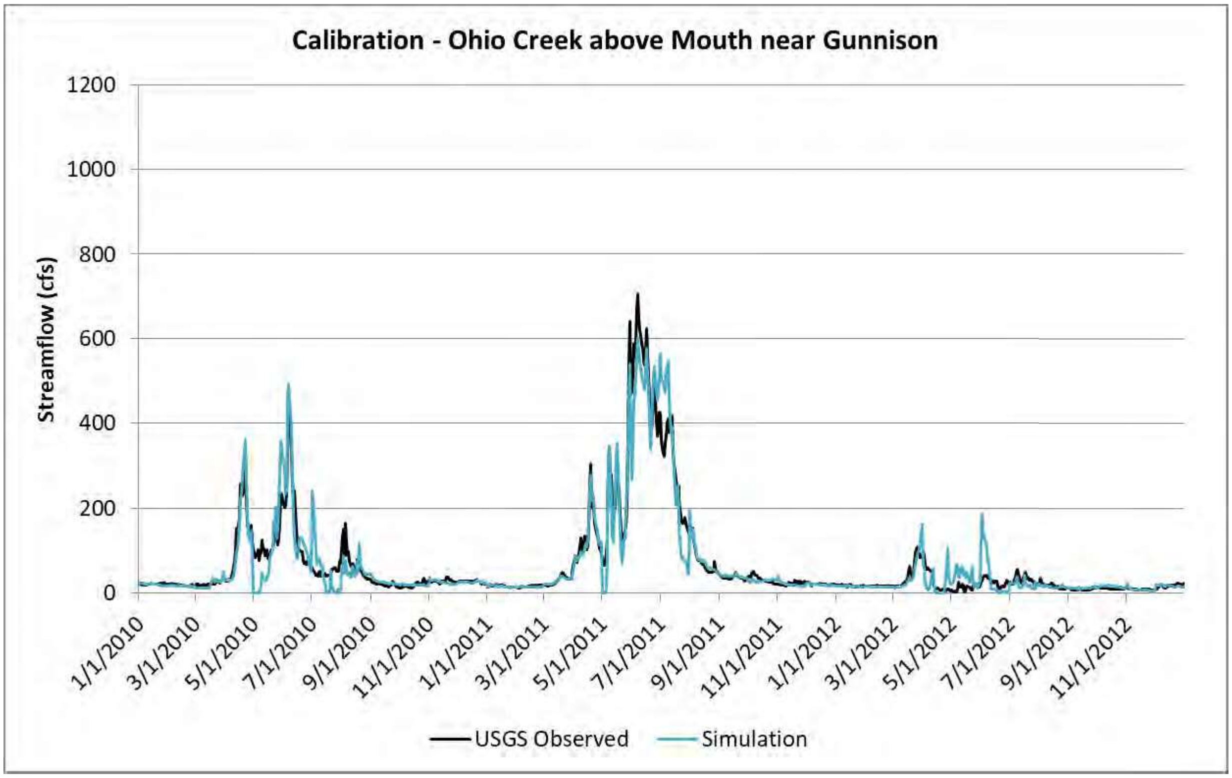

Figure 13: Daily Calibration Time Series - Ohio Creek above Mouth near Gunnison, 2010-2012

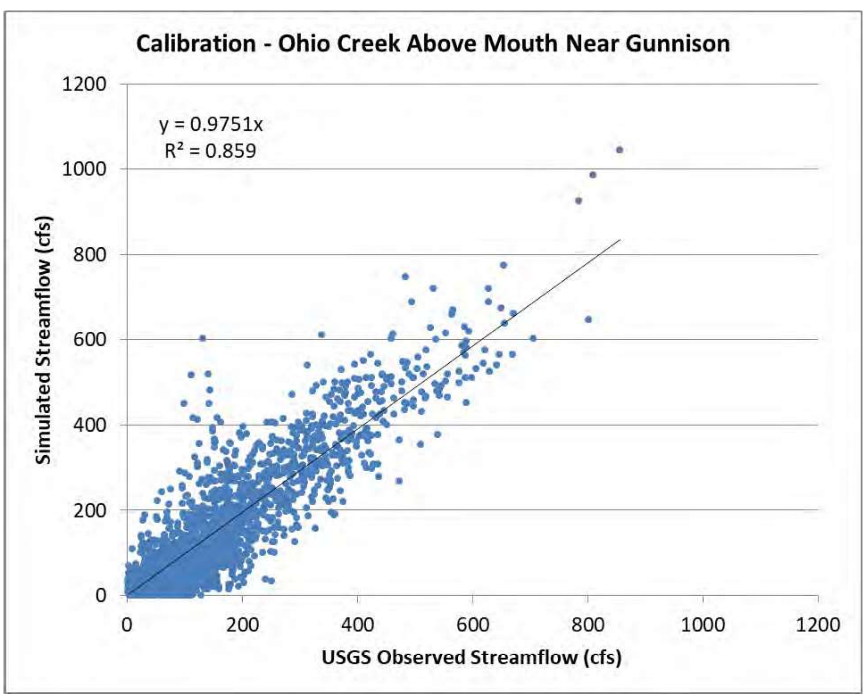

Figure 14: Daily Calibration Scatter Plot - Ohio Creek above Mouth near Gunnison, 1998-2017

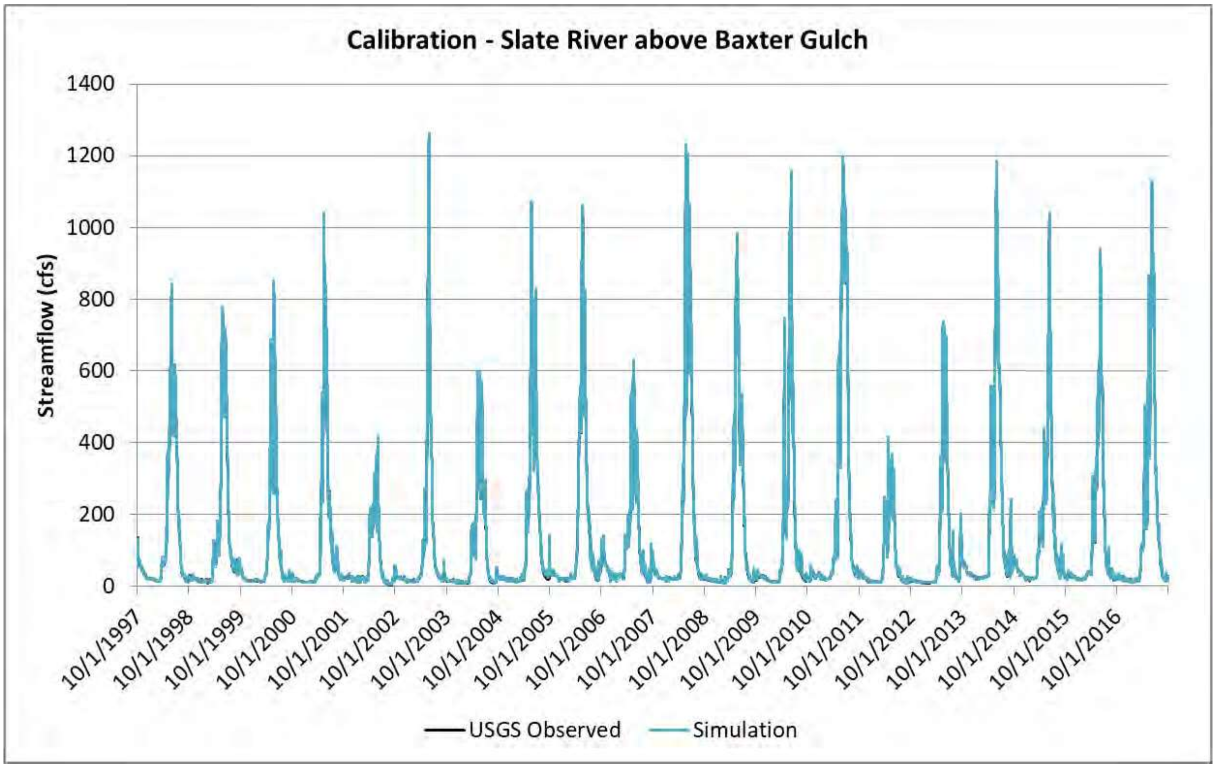

Figure 15: Daily Calibration Time Series - Slate River above Baxter Gulch, 1998-2017

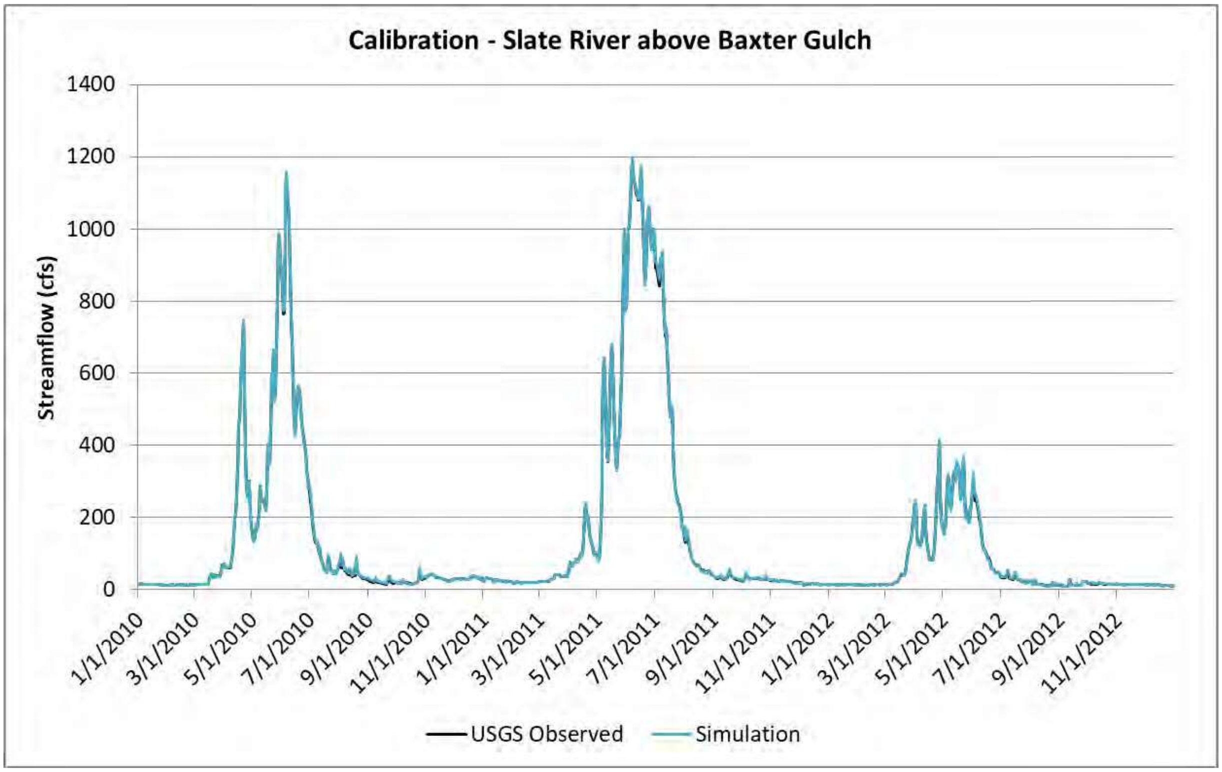

Figure 16: Daily Calibration Time Series - Slate River above Baxter Gulch, 2010-2012

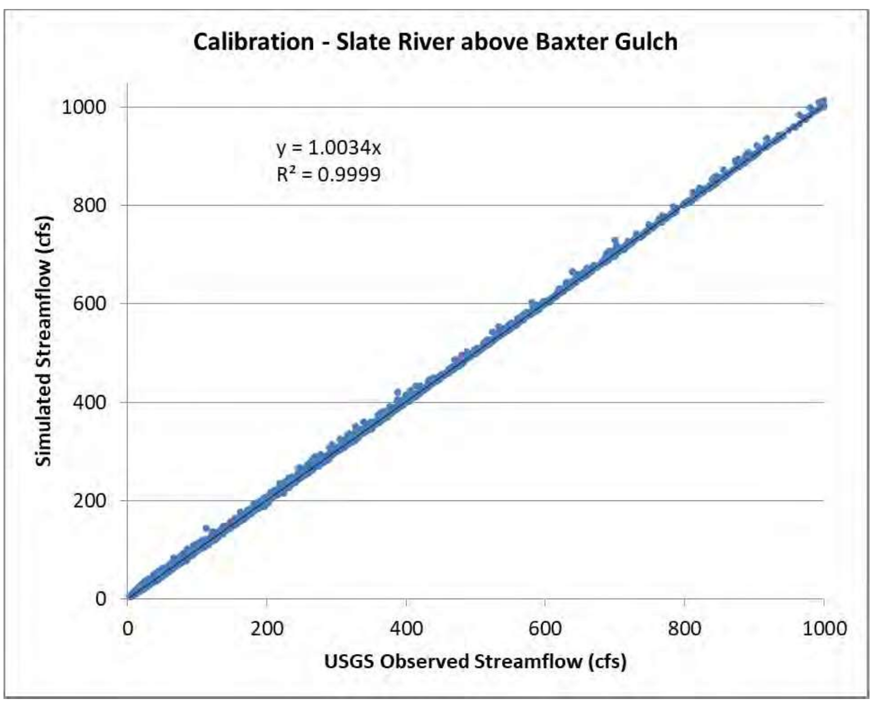

Figure 17: Daily Calibration Scatter Plot - Slate River above Baxter Gulch, 1998-2017

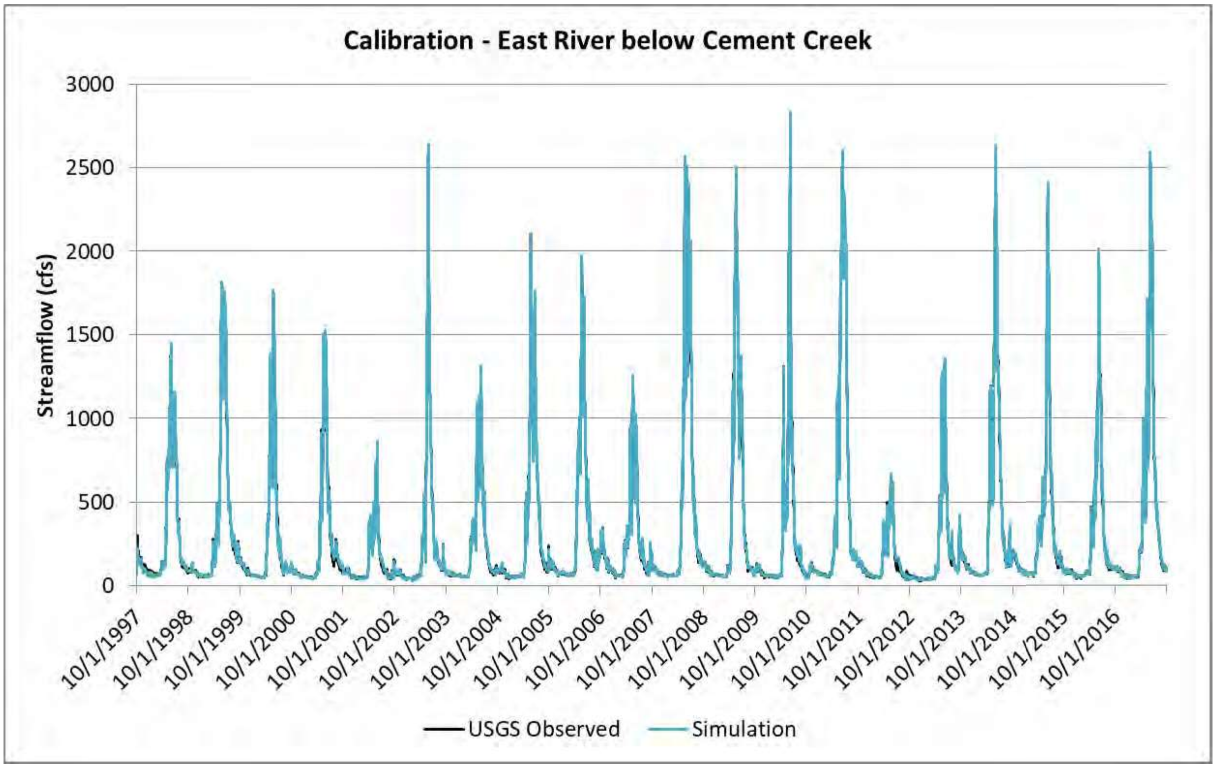

Figure 18: Daily Calibration Scatter Plot - East River below Cement Creek, 1998-2017

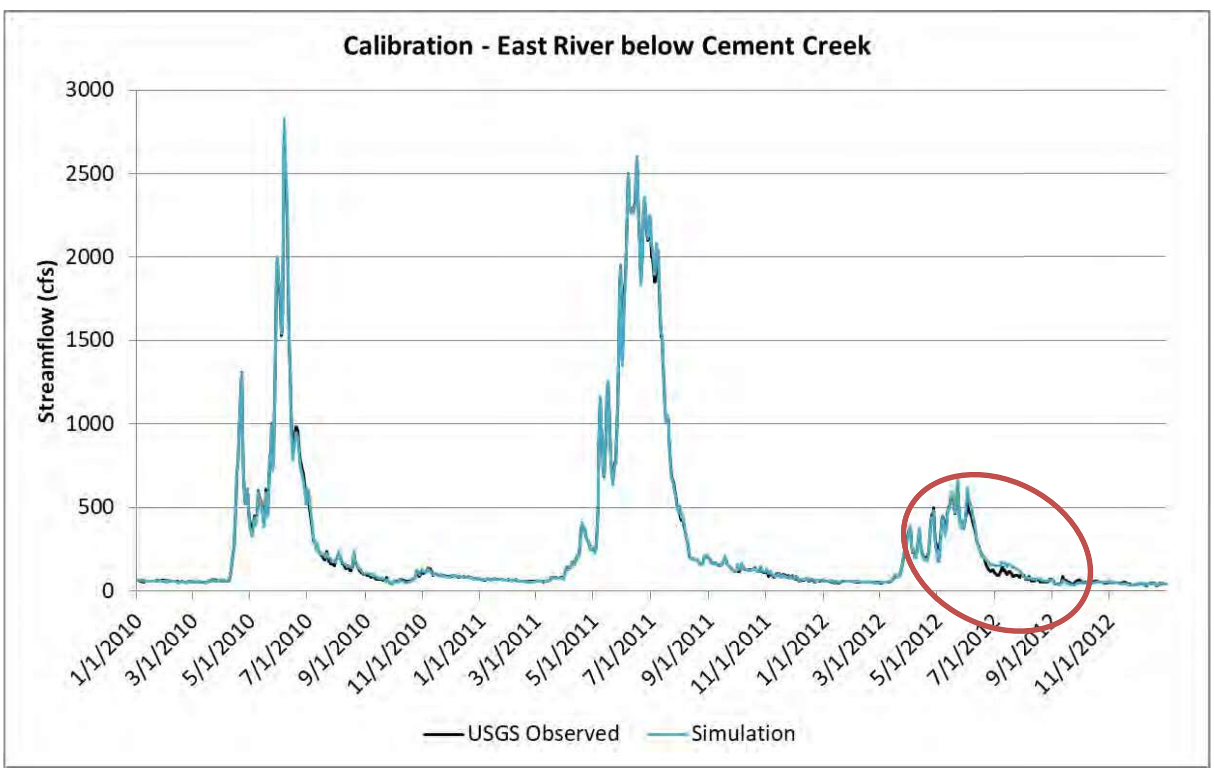

Figure 19: Daily Calibration Scatter Plot - East River below Cement Creek, 2010-2012

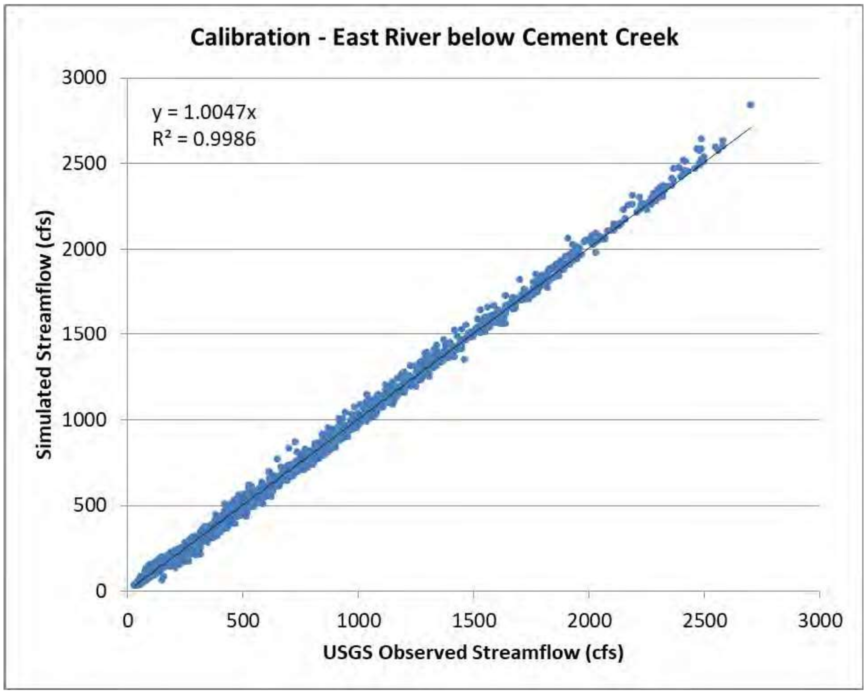

Figure 20: Daily Calibration Scatter Plot - East River below Cement Creek, 1998-2017

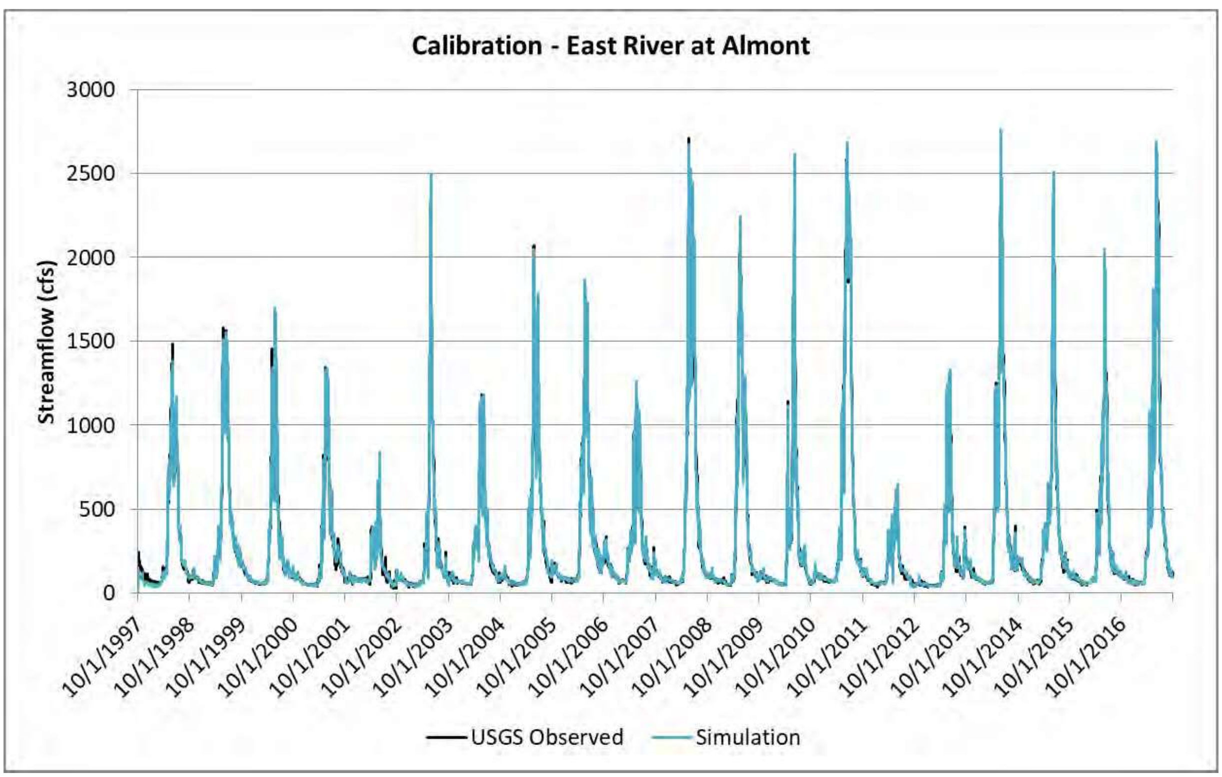

Figure 21: Daily Calibration Scatter Plot - East River at Almont, 1998-2017

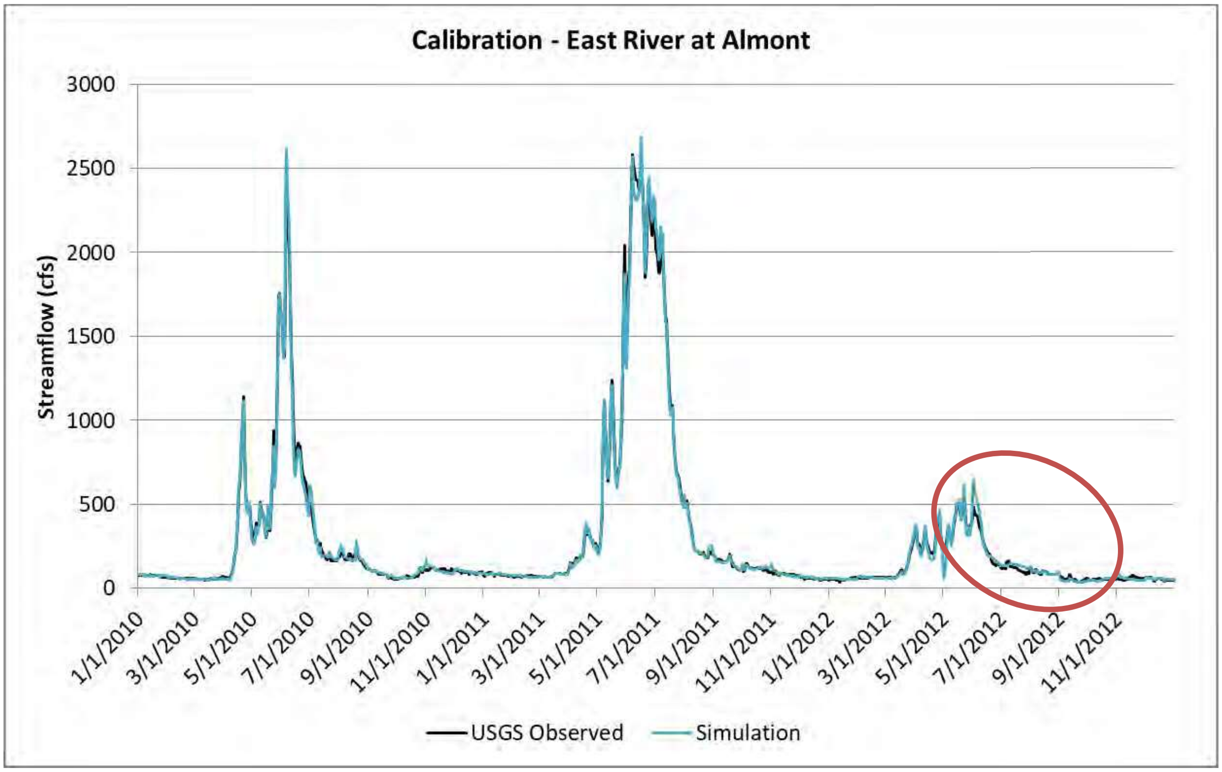

Figure 22: Daily Calibration Scatter Plot - East River at Almont, 2010-2012

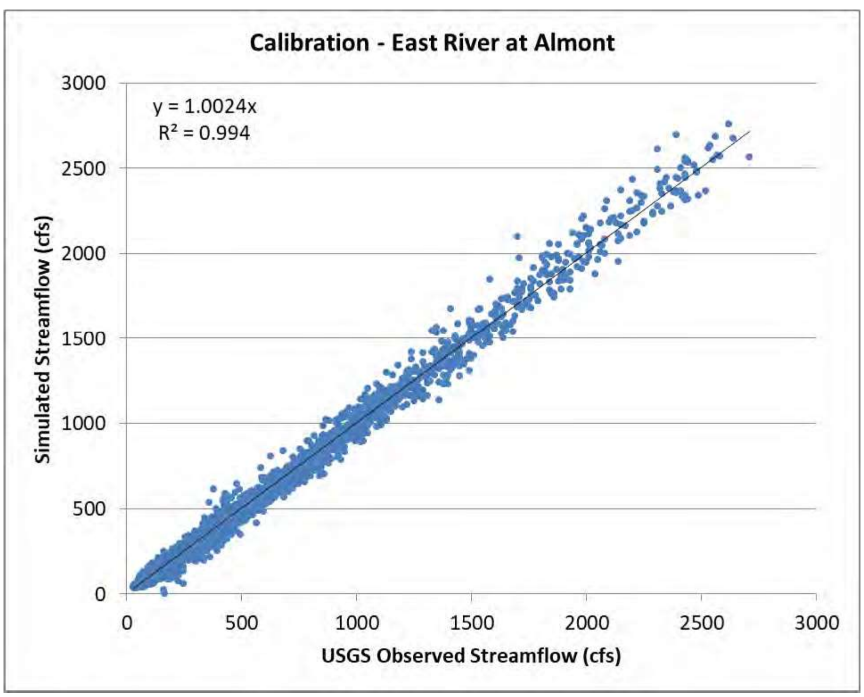

Figure 23: Daily Calibration Scatter Plot - East River at Almont, 1998-2017

Appropriate Model Applications

StateMod is a water rights allocation modeling platform. The objective of the platform is to provide information about water availability based on the prior appropriate doctrine and Colorado water right administration. Operations in a basin that depend on “gentleman’s agreements” to divert water out of strict priority are not accurately reflected in the model. In addition, the model is not a physical process model. It depends on historical streamflow, diversion, and reservoir records, estimates of consumptive use, and return flow parameters set by the modeler. Therefore, the results are limited by the quality of the records.

The modeling platform is most appropriately used as a comparative tool. Results from many “what if” scenarios can be compared and contrasted to understand the relative magnitude of impacts from a change in demand or operations. For example, a scenario with a new reservoir could be compared to the current use scenario to determine the water availability for storage, changes to peak flows and late season flows at a location downstream of the reservoir, or changes to water supply for reservoir users. This makes StateMod an ideal tool for large scale planning efforts and has been successfully used by the State of Colorado to support the Colorado Water Plan (which looked at multiple growth and development scenarios), Colorado River Compact Compliance, Endangered Species Recovery Programs, and by the Gunnison, Yampa/White/Green, and North Platte Basin Roundtables to support their Basin Implementation Plans.

It is not appropriate to use StateMod to determine precise physical streamflow measurements because StateMod does not consider physical stream channel parameters or routing processes. For example, it assumes that reservoir releases are delivered to downstream diversions in the same time step as the reservoir release with no lag or attenuation. This is a model simplification that generally does not impact monthly planning efforts but can significantly impact the accuracy of daily StateMod streamflow results, depending on the size of the basin and the channel grade.

It is important to consider how natural flow was estimated by the model in order to understand the uncertainty of model simulated streamflow throughout a basin. As discussed in the “Natural Flow Development” section above, natural flows are estimated at streamflow gages based on historical records of water use and distributed to ungaged locations based on gains between streamflow gages. Therefore, stream reaches with long-term, high frequency and accurate records of streamflow and diversions have less uncertainty in natural flow estimates. Ungaged tributaries or stream reaches above streamflow gages have the most uncertainty because natural flow estimates rely on limited data. Limitations in the streamgage network impact the level of uncertainty for streamflow results.

Regardless of these constraints, the Gunnison StateMod model is still appropriate to use to explore "what if" scenarios in a comparative manner. The following are a few examples of comparative opportunities the model can assess to improve watershed health:

- How much additional flow can be generated from voluntary, compensated fallowing and is the saved water re-diverted without the benefit of shepherding?
- How can improvements in conveyance and/or application efficiencies improve river flows and how do they impact downstream water available to senior water rights?
- How can storage be used to reduce consumptive shortages and improve streamflows?